Cool Test Stand Design Concept

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Introduction

This note will explore the design of a test stand for the DeCam project. The first test stand will serve as a learning station. Here we will collect all the things needed to read out a large area CCD and learn how to use them. We hope that the first design will be close enough to what is needed so that we can just copy it with minor modifications for the production test stand. There is a lot required before one can do anything with a CCD. We will start with the big picture and try to list all the stuff that needs to be collected.

The cooling scheme is a small part of what is needed for a CCD test stand. Most of what is outlined here is needed whether the CCD is cooled by a cryostat or by thermoelectric coolers. Most of what is outlined here is included in each camera built for The Amateur Sky Survey (TASS).

The Big Picture

Below is a rough layout of the lab space required for the test stand. Figure 1. There is a lot of stuff. Note that the

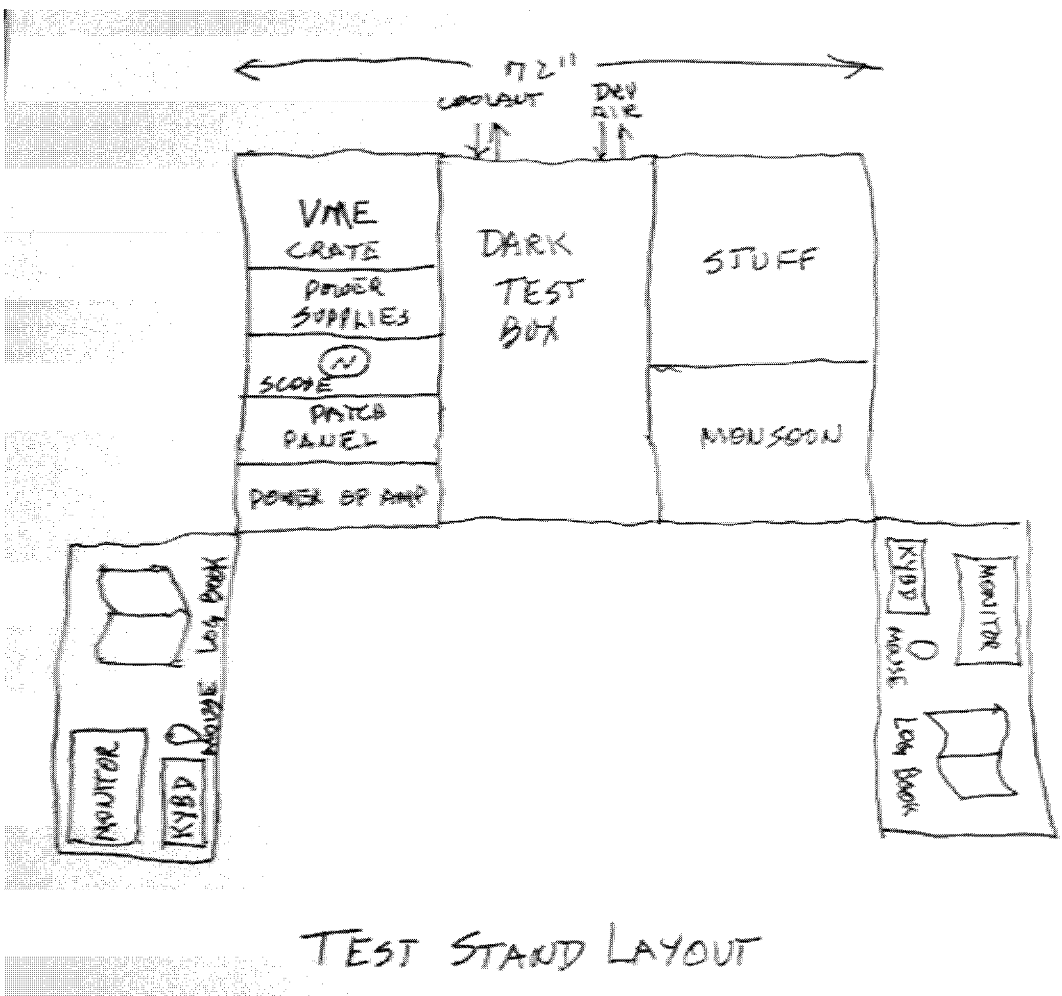


Figure 1. The Test Stand Layout

LBNL cryostat box that we have been discussing is just one small item that would live in the dark box. At this time I do not understand all the things contained in the Monsoon system. It may contain the things needed for control. It may be missing vital items. Since I will surely need a DAC to control the cold plate, I have shown a VME crate. This crate will have a monitor, a cpu module, a keyboard and the other computer things. It will house DAC channels, ADC channels, and control registers. I am told that all these things are available in PREP.

The purpose of the VME crate is to control the test stand. We will need to measure and control a lot of things. To give an idea of what might be needed, each TASS system includes 32 ea. 16 bit ADC channels, 16 ea. 8 bit DAC channels, 8 thermometer channels, 16 limit switches, 8 pulse width controlled outputs, 16 bits of output register, and 16 bits of input register. I use almost everything.

The Monsoon system may have built in general purpose modules. If so, we will use them. It is important to be able to measure and control everything going on in the test stand. There will be a lot of alarms and limits. It will be important for the test stand to notice conditions that the operator does not notice and tell the operator. "The bias supply has tripped". We want to try to prevent destroying too many of these valuable CCD chips. A good control system will help.

If one needs to take a measurement on a CCD, it is not practical to open the box since the CCD will then be exposed to light and the reading will likely not mean anything. The LBNL documents indicate a rather complicated procedure to reset after bright light exposure. I have therefore proposed a system where all the device pins are brought out through buffers that are fast enough to preserve the signal shape These signals are brought out to a panel where they can be viewed by an oscilloscope. I can't emphasize enough how vital this is. There will be times when nothing works. There is no image produced. We will need all the built in tools that we can muster to tell us why.

The main drive for the cold plate is a power operational amplifier. A suitable device would be the Kepco BOP series. The lab has a number of these which are otherwise about $1000. Other power supplies will be needed. Rack space is shown for them.

I have shown the Monsoon system in a second rack mount along with space for things that I have not yet thought out. Stuff will accumulate before we can take data. I show a second desk with a monitor for the images that are read out by Monsoon. I think we will always want to have at least two displays. One will show operating conditions for the test stand, the second will be used to display images.

The Dark Box

The central feature of the test stand is a big black box. Figure 2. A good size might be 24" x 24" x 48" high. It is probably easiest to make this of wood. It should be metal lined both to insure that it is light tight and to provide shielding for the contents. A thin sheet copper lining will do. I have shown the test box as a vertical box. My test box at home is horizontal and 8 feet long. I needed a longer distance because I wanted to also test my lenses and a long distance was required to get a focus.

The main features inside the box are a cable entry, a target, a flat field box, and a cold box with it's associated printed circuit board.

Connections coming into the box will be protected from electromagnetic fields. CCD-World lists many ways to kill a CCD. One lost a CCD from a nearby spot welder. At Fermilab, I can imagine a welder arriving at any time to fix something. There goes a CCD. So we will protect the CCD from anything we can imagine except a direct lightning strike. This requires (simple) circuits inside the box. Mostly these are diode clamps for every line entering and leaving. We also want to be able to look at the signals on all the CCD pins without exposing the pins to the outside world. This will be done by clamped buffer amplifiers in sockets. If we do something awful looking at the pin the buffer amplifier will give up the ghost to protect the signal pin. The following circuit sketches do not show

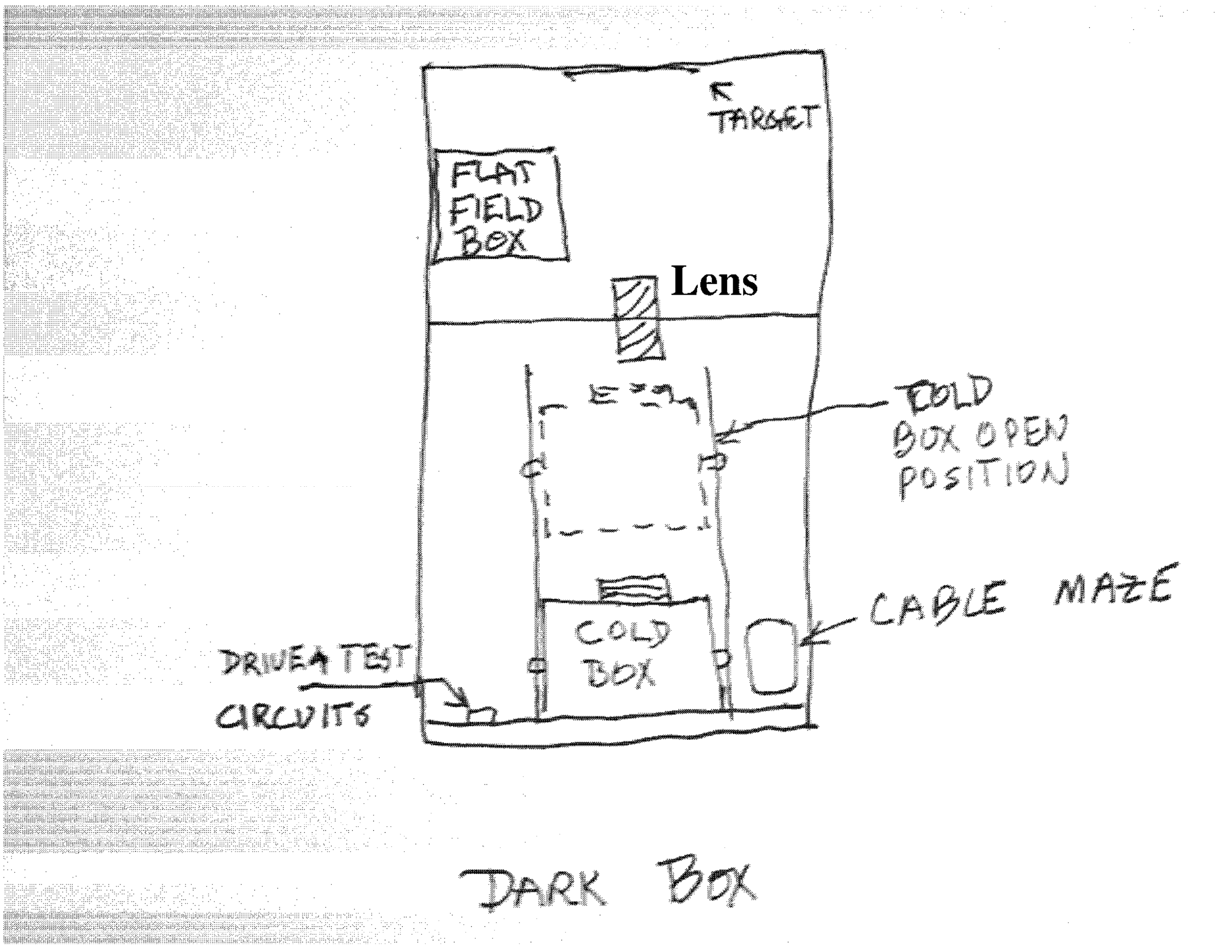


Figure 2. A large dark box is the central feature of the test stand.

all the parts. There will be circuits to protect from static transients included.

There are a lot of wires that have to go into the box. We will always be making changes, adding and removing signal lines. To make this easy, the connections are brought into the box through a dark maze with a removable cover.

The sketch shows the cover of the cold box with a quick clamp. When the clamp is released, the cold box cover can be raised up on slides for easy access to the cold plate.

There is a lens and a target to produce a test image on the CCD. A flat field box is needed to allow measurement of the defects in the CCD. We show a flat field box that can be moved into position which casts an out of focus image on the CCD. I envision this box on slides so that it can be moved with strings from outside the box. We will want to take target images and flat fields without opening the box. For a shutter we simply turn on a light inside the box.

Several targets might be useful. The targets could also be mounted on slides with strings for selection from outside the box.

Below the cold box is a large printed circuit board with protection and measurement circuits. This is also a good place for the bias voltage switches and a current limiting Vdd supply. By supplying Vdd from a simple current limited source, burnout of the output amplifier can be avoided.

The Cold Box

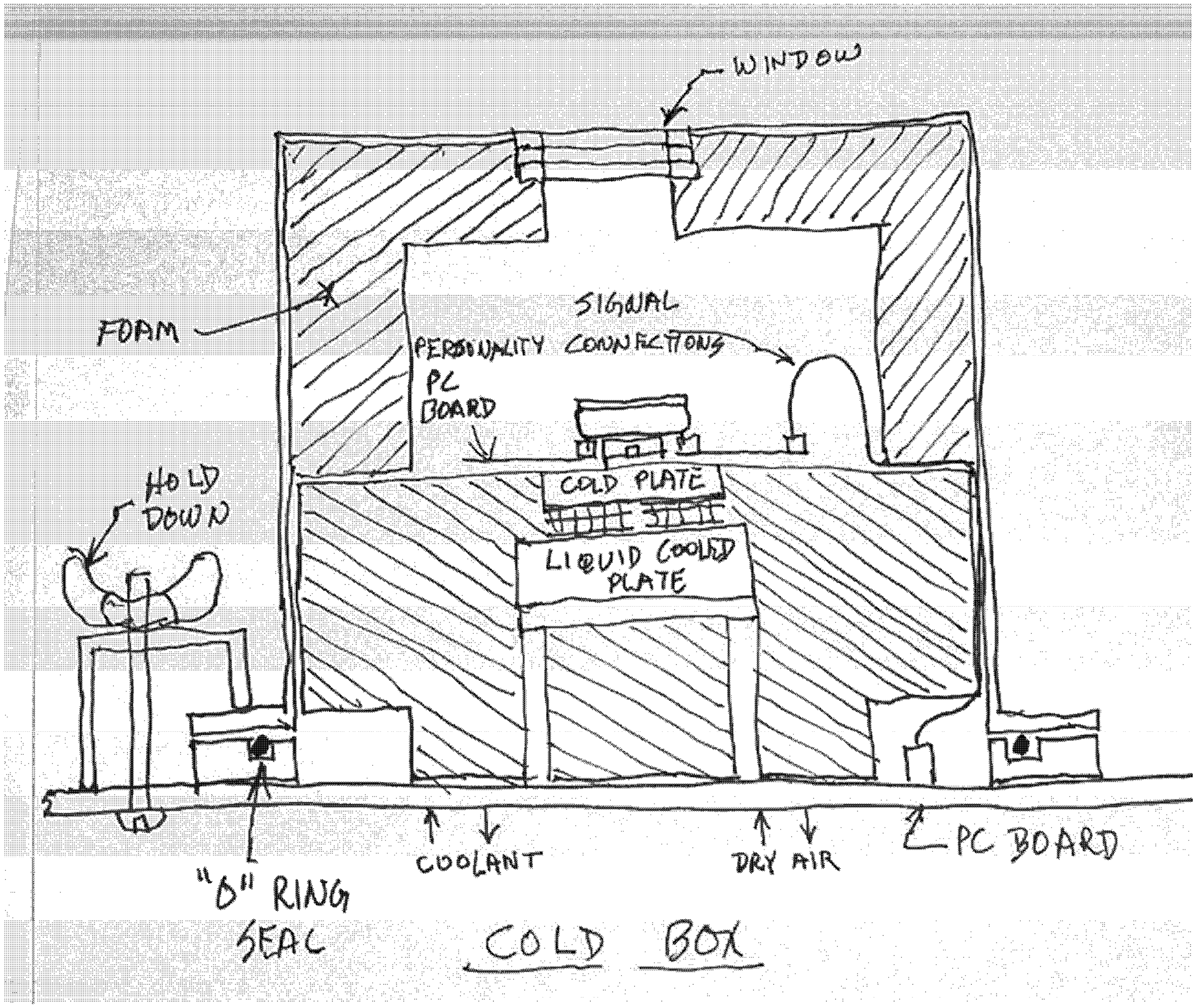


Figure 3 The Cold Box

A large printed circuit board forms the base of the cold box, Figure 3. A base ring with an "O" ring for sealing is glued to a PC board which forms the base for the cold box cover. The printed circuit board forms one seal for the dry air in the cold box. Penetrations through this PC board are made for the liquid coolant and the dry air connections.

A metal removable cover provides the other surface of the cold box. The end of the cover contains a multi-pane window to reduce heat loss.

Using the Melcor design calculator we find that with the selected TECs, we can reach –70 C with two stage devices if 2 1/2" of foam insulation is used. The devices selected are 4 each 2 SC 055 045-127-63. These devices are 40 mm square. Since the temperature limit falls off very quickly, we should be able to work comfortably at –60 C using –20 C coolant. Unfortunately, Thermoelectric Coolers become less efficient as the temperature is reduced.

The large PC board base contains circuitry to protect and sense the leads connected to the CCD. In the cold chamber, a "personality" printed circuit board will contain the clock driver circuits so that the large clock currents do not have to be driven any significant distance with the resulting noise and bounce problems. These small boards will be fabricated for each type of device tested and will match the general purpose circuitry of the base printed circuit board to the specific pins interfaced by the personality board. Short cables routed by the insulation will connect the base printed circuit board to the personality board. We have shown a ring where there is no insulation around the base to make these connections convenient

The Cold Plate Assembly

Figure 4 is a sketch of the cold plate assembly. The cold plate is glued to a set of 4 thermoelectric coolers which are in turn glued to a liquid cooled plate. The whole assembly is screwed to stand off posts to position the assembly above the printed circuit board to which it is glued. Coolant fittings (not shown) supply the coolant. The whole assembly is foamed to fit the cover. Figure 5 is a sketch of the cold plate. A row of mounting screw holes allows for flexible mounting of CCD devices. There is room for two 2k x 4k LBNL devices side by side. This allows

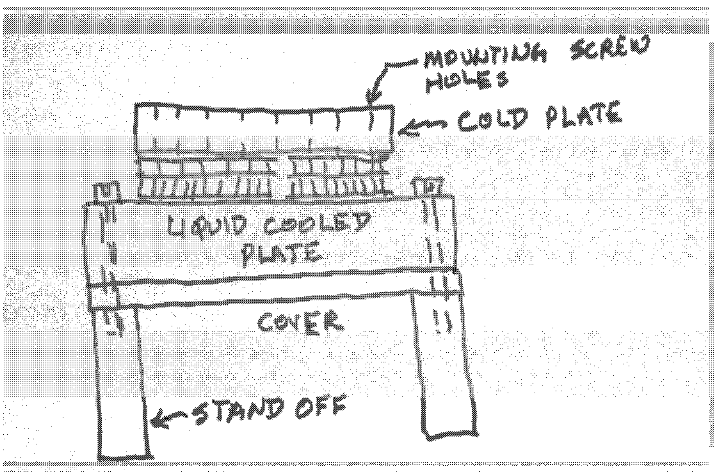


Figure 4 Cold Plate Assembly Sketch

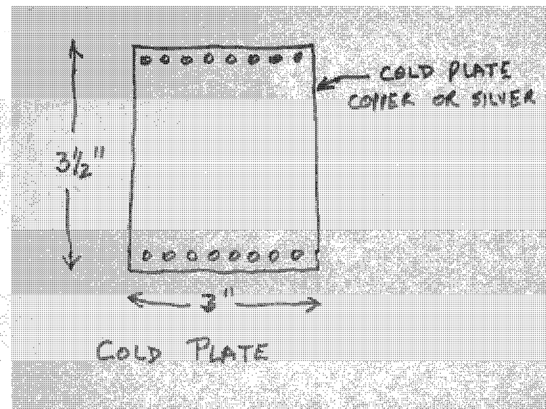


Figure 5 Cold Plate Sketch

twice the test through put or for comparison of a test device with a reference device.

We suggest that the cold plate be made of silver. It will no doubt be a nuisance to fabricate a silver plate. It is estimated that the settling time for a silver plate is about half that for copper which is the next best material. The time to settle to a fraction of a degree C might be 1/2 hour for copper and a little more than 15 minutes for silver. Multiplied by many hundreds of cooling cycles, the saving in labor cost greatly outweighs the cost of the silver. The times are short enough that it is not efficient to wander away and try to do something else.

CCD Mounting

Figure 3 shows a window frame package mounted to the cold plate. This is done by mounting the CCD in a socket which is mounted in a personality printed circuit board. The board has a hole in it to match a cold finger which is screwed to the cold plate. Thermal grease is usually sticky enough to hold such an assembly together for test. If not, hold down screws can be used through the printed circuit board to the cold finger.

To test the LBL type precision mounting, a mounting block is prepared which matches the screw holes in the cold plate. This is then attached to the precision LBNL block with countersunk screws as shown in Figure 6. Figure 7 shows this assembly mounted to the cold plate. A personality printed circuit board is mounted to the mounting block for routing connections and for the clock line drivers.

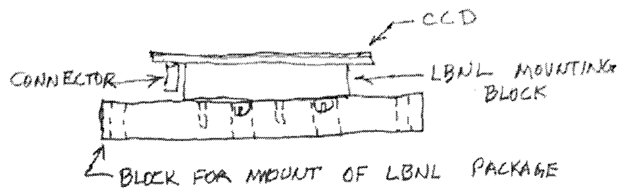


Figure 6 A LBNL type package mounted to a mounting block

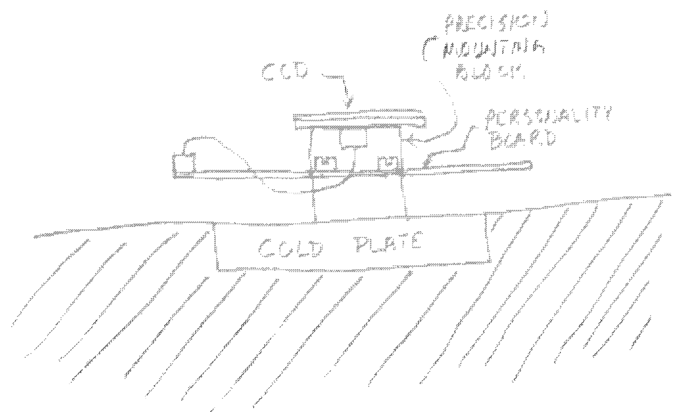


Figure 7 The LBNL package mounted to the Cold Plate with a personality card.

Protection and Measurement Circuitry

The printed circuit board that supports the cold box is a good place to locate protection circuits. Probing the device lines is one of the causes of device failure. By providing buffer amplifiers on all the lines they can be examined with very low risk to the CCD. A four layer printed circuit board is suggested with top and bottom ground plane and the circuits on the inner two layers. This will guard the test lines from accidental contact over most of their length. We suggest a circuit such as Figure 8 for most of the 40 device pins. The bias and Vdd lines will require somewhat different handling. These are DC signals and can be protected with large series resistors and clamp diodes. The "Test Board" of figure 8 is intended to be some sort of pin board mounted in the rack near the oscilloscope.

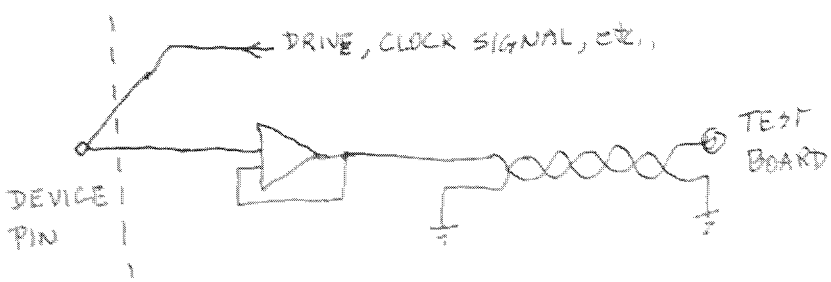
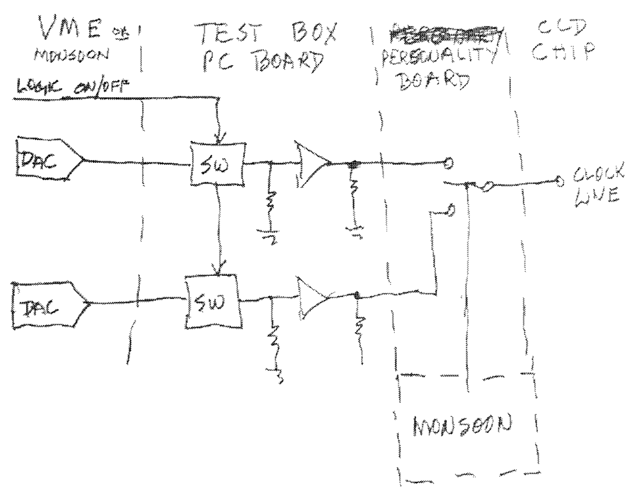


Figure 8 Buffering of the CCD Pins

Clock Line Drivers

The clock lines of a CCD have high capacitance. It is necessary to control the rise and fall time for proper charge transfer down the registers. Ringing on the drive lines can confuse the charge transfer. Currents can be quite high, amperes. If these high currents are carried long distances, then there is a great opportunity for cross talk, bounce and other bad things. It is suggested that the clock drive circuits be as close as possible to the CCD. It is suggested that this is a better use for the real estate on the back of the AlN substrate than for mounting the ADC. Hopefully space will be found for both.

Figure 9 shows the general scheme for driving the clock lines. A DAC generates the level for the clock lines. One DAC for each of the High and Low values. These DC levels are connected to a opto isolator switch in on the test box PC board. A control logic signal turns the voltage on when appropriate. This is necessary if we want to know the state of the clock levels at all times. DACs can turn on with any output voltage configuration. To make sure of the clock levels, the DACs are first set to their desired levels. Then they are read back by the data acquisition system to make sure that they have been set correctly. Then the levels are turned on by a logic register. The clock levels are buffered, then connected to the personality board or the switches on the AlN substrate. The logical clock sequence is now provided by the Monsoon system or the equivalent to actually perform the clock line drive. By providing sufficient bypass capacity on the personality or AlN board, the pulsed clock currents can be kept local.



;Figure 9 Clock Line Drive Scheme

Bias Power Supplies

CCDs require a number of bias voltages to function. These require either very low current or a small controlled current in the case of Vdd. Since these are complicated semiconductor devices, it is possible to form SCR's in the material through the wrong combination of bias potentials. If such a combination occurs it destroys the device. Figure 10 is the general scheme for generating such bias voltages. A DAC generates the bias voltage. As before it is read back by an independent measurement system. While this was "nice" for the clock levels, it is essential for the bias voltages. An opto-isolator then turns on the bias voltages in a controlled sequence. A control system should turn them on in the proper order, then they should be read back at each step to make sure the previous step was successful. This may appear to be overdoing it, it is probably not being too safe.

The Vdd supply is a special case. This is the supply for the output amplifier. It normally runs at a few ma of current. A few ma + delta can burn it out. OK, it might be good for a factor of 10 but not much more. I can assure you that this is the most common way to destroy a CCD. Well, I can assure you that I have destroyed more CCDs by this error than by any other. The circuit of Figure 11 is designed to protect the output amplifier while providing a stiff source that does not limit the performance of the output amplifier. These parts would live on the printed circuit board to provide the greatest protection from accidental contact. Note that the usual way to kill this amplifier is by accidental static discharge, or even contact with a capacitor such as that involved in charging a cable when it is attached to the output amplifier.

These circuit sketches do not show all the parts. Circuits with perform similar functions are found in the LBNL

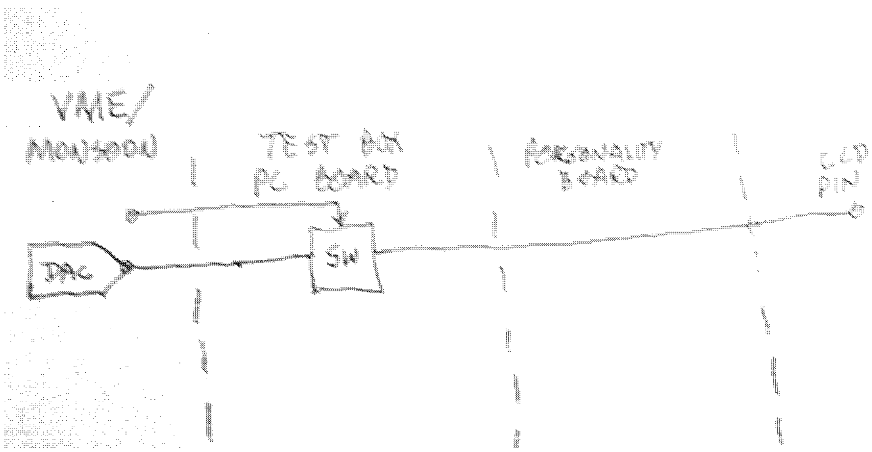


Figure 10 Bias Drive Scheme

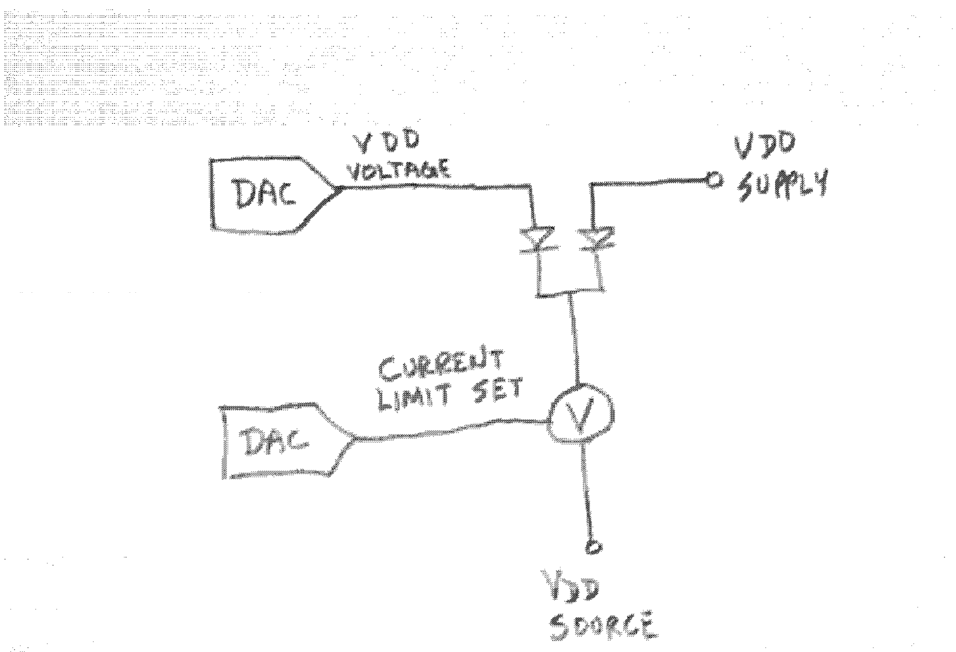


Figure 11. Vdd Supply

documents. Some of these functions might be available in the Monsoon system. What is used will depend on what is available and whether standard circuits can be use to provide the protection required. Some protection will need to be very local to the CCD chip.